SUSCEPTIBILITY OF LAKE TROUT (SALVELINUS NAMAYCUSH) SPAWNING SITES IN ONTARIO TO ACIDIC MELTWATER

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The Ontario Fisheries Acidification Report Series has been established by the Ontario Ministry of Natural Resources to document findings from studies conducted as part of the Fisheries Acidification Program. These reports are intended to contribute to our knowledge of acidification effects, but they should also be of general interest to fisheries managers.

These reports are basically progress reports. Much of this information will appear later in journal papers.

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Susceptibility of Lake Trout (*Salvelinus namaycush*) Spawning Sites in Ontario to Acidic Meltwater

ABSTRACT

Two hundred and twenty-one confirmed lake trout (*Salvelinus namaycush*) spawning sites in inland Ontario lakes were surveyed by questionaire in order to identify the proportion of sites susceptible to acidic meltwater. A set of conservative criteria was established to identify susceptible sites. Seventy-eight percent of surveyed spawning sites were located in water with a mean depth of less than 2 m. Eighty percent of surveyed sites were located less than 10 m from shore. All but 5 of 208 sites for which substrate composition was described were located on non-calcareous substrate. All but 1 of 221 sites described were 20 m or more from an inlet. Of the 202 sites which could be assessed according to the criteria established, 129 or 64% had characteristics which would make them susceptible to influxes of acidic meltwater.

Susceptibility of Lake Trout (Salvelinus namaycush) Spawning Sites in Ontario to Acidic Meltwater

INTRODUCTION

Depressed pH and elevated inorganic aluminum concentrations are associated with the spring influx of acidic meltwater to the surface waters and littoral zones of poorly buffered lakes in Ontario (Jeffries et al. 1979, Scheider et al. 1979, and Gunn and Keller 1984). Several factors combine to make the lake trout (Salvelinus namaycush) particularly susceptible to damage from these conditions. Firstly, the relatively immobile larvae of the lake trout, a fall spawning species, are developing on spawning shoals during the spring (Gunn and Keller 1984). Secondly, in toxicity tests, early life-history stages of fish are generally more sensitive to acids and metals than are adults of the same species (McKim 1977). Thirdly, lake trout spawning sites are located close to shore and in shallow water in the small inland lakes which are sensitive to acidification (Martin and Olver 1980). Meltwater toxicity has been postulated as a mechanism for the recruitment failure which has been observed in acidified systems (Haines 1981).

The purpose of this report is to estimate the proportion of lake trout spawning sites in Ontario which are susceptible to influxes of acidity. In order to maximize the number of spawning sites described, I have summarized the physical and biological characteristics of sites without regard to whether or not the lake in which the site is located is sensitive to acidification. The exception to this rule is that the Great Lakes were eliminated from consideration both because they are not sensitive to acidification and because they are known to contain lake trout which spawn at great depths (Martin and Olver 1980). I have assumed that the characteristics of sites would not differ between acid-sensitive and non-sensitive inland lakes. A secondary reason for surveying spawning sites in as many inland Ontario lakes as possible was to compile information which could be used for a variety of other purposes, for example, for predicting the effect of lake level fluctuations on lake trout spawning.

METHODS

Survey procedure

A questionnaire (Appendix 1) was distributed to fisheries workers in Ontario known to have made detailed observations of lake trout spawning sites. They were asked to fill out a questionnaire for each confirmed site (i.e. a site at which lake trout adults in spawning condition or deposited lake trout eggs had been observed) that they were familiar with. If they were unable to complete questionnaires for all of these sites, they were asked to select a sample of sites which was representative of the physical characteristics of all of the confirmed sites. A list of respondants and their affiliation is given in Appendix 2. Additional information on confirmed lake trout spawning sites was obtained from the following unpublished Ontario Ministry of Natural Resources (OMNR) data reports: Blais et al. (1984), Liimatainen (1984), Raine and Weilandt (1980), and Snucins (1984).

The questionnaire extracted general information on the lake in which a site was located and more specific information on the extent of spawning activity observations, the life stages of lake trout observed, the location of the spawning site in the lake, and additional physical characteristics of the site and of the nearest shoreline. Respondants were asked to mark the sites described, as well as additional suspected sites, on a contour map of the lake. Completed questionnaires and contour maps are on file at the Environmental Dynamics Section of Fisheries Branch, OMNR, Queen's Park, Toronto.

Only part of the information contained in the questionnaire returns has been used in assessing spawning site susceptibility to acidic meltwater.

Site vulnerability assessment

Discussions with G. Beggs, J. Gunn (both with Fisheries Branch, OMNR), and T. Stewart (Algonquin Region, OMNR) established a priori that four critical spawning site characteristics would determine whether or not the site would be considered vulnerable to influxes of acidic meltwater, apart from considerations of overall lake sensitivity to acidification:

1) Depth of water at site. Acidic meltwater at or close to $0^{o}C$ is less dense than lakewater at $4^{o}C$ and therefore forms a layer typically several metres thick which may cover the entire surface of the lake (Jeffries et al. 1979). The thickness of this layer varies with lake morphometry, meteorological factors affecting physical mixing, and the magnitude of runoff volume to lake area (Jeffries et al 1979). Lake trout spawning sites in shallow water are therefore more vulnerable to acidification than deep-water sites.

2) Proximity to shoreline. Spawning sites close to shore would receive direct runoff from shore as well as meltwater from inlets and the snowpack on lake ice. In addition, acidic meltwater may accumulate between the shoreline and the receding ice cover (Gunn and Keller 1981).

3) Proximity to inlets. Spawning sites close to a river or stream carrying acidic meltwater are more likely to be subjected to toxic conditions than sites distant from inlets.

4) Composition of substrate. Though almost all inland Ontario lake trout lakes are situated on the granitic Canadian Shield (Beggs et al. 1985), it is possible that some spawning sites are located on pockets of calcareous (limestone-bearing) substrate which would buffer inputs of acidity.

Empirical data on the behaviour of meltwater in lakes are inadequate to predict accurately which sites will be adversely affected. However, on the basis of Jeffries et al. (1979) and discussions with J. Gunn and T. Stewart, I set the following limits to the above criteria for site vulnerability: 1) mean depth of water at site less than 2 m, 2) nearest edge of site less than 10 m from shore (mainland or island), and 3) site located on noncalcareous substrate. A site would have to meet all of these criteria to be considered vulnerable. If the site is less than 20 m from an inlet however, it would not have to meet any additional criteria. I believe that these limits are conservative, i.e. that they will underestimate the number of vulnerable sites.

RESULTS AND DISCUSSION

Lake location, area

Detailed descriptions of 221 lake trout spawning sites in 82 lakes were obtained. Appendix 3 lists lake name, district, latitude and longitude and number of sites for each of these lakes. These lakes are distributed widely across the Province of Ontario (Fig. 1) with the greatest concentration in south-central Ontario - an area which receives high acid loading (Scheider et al. 1979). All are located on the Canadian Shield or near its edge (Beggs et al. 1985).

Spawning site depth

The majority of sites are located in very shallow water; 22% of sites have a mean depth less than 1 m and 78% have a mean depth less than 2 m (Fig. 2). The deepest site has a mean depth of 6 m.

There is a slight tendency for site depth to increase with increasing lake area (Fig. 3). The Pearson correlation coefficient for mean site depth and the logarithm of lake area is 0.39 ($P = 0.0001$). When the two largest lakes and the single site at a depth of 6 m are removed from the data set, the correlation decreases to 0.25 ($P = 0.0007$). Martin and Olver (1980) also found that spawning sites tend to occur at an increasing depth in large lakes and suggested that it is because longer fetches allow greater wave action, deeper cleaning action and higher oxygenation.

G. Beggs (pers. comm.) pointed out that visual methods would only be effective in identifying shallow-water sites (i.e. those at depths less than about 2 m). This would lead to an exaggerated estimate of the susceptibility of spawning sites to acidification if additional sites were present at greater depths. Of the 201 sites with estimated or calculated mean depth, 176 were identified visually. The most common method was to cruise suspected spawning areas by boat at night with the aid of underwater lamps. The remaining 25 sites were identified with sonic tracking gear. As the sonic gear has a practical depth range of 30-40 m (J. Kelso, Department of Fisheries and Oceans, Sault Ste. Marie, pers. comm.), it provides the opportunity to test for a bias in visual site identification. The mean depths of sonically and visually identified sites were 1.40 m and 1.34 m, respectively. The difference between means is not significant (T-test assuming equal variances, P = 0.7047). Therefore the depth distribution of sonically and visually identified sites combined probably reflects the true distribution of lake trout spawning sites in inland lakes.

Distance from shore

Eighty percent of spawning sites are located less than 10 m from shore (Fig. 4). Excluded in this analysis are sites known to be "close" or "next to" shore but for which the distance was not estimated numerically. The 4 sites furthest from shore were at distances of 200, 250, 350 and 1000 m and were found in Lakes Temagami, Drag, Birch and Aylen, respectively. Of the sites less than

10 m from shore, 90% were within 5 m of shore (Fig. 5). If no measured or estimated distance from shore was given for a spawning site, but the site was shown on a contour map as starting at the shoreline, the distance was listed as 0 m. Some of these sites may actually have been 1 or 2 m from shore.

I suspected that the near-shore distribution of spawning sites was partly a reflection of the practice of shoreline cruising by site identification crews. The distribution of only those sites identified with sonic gear would not be biased in this way. The mean distance from shore of sonically identified sites (mean = 8.35 m, SD = 19.64, n = 28, median = 1.50 m) is less than that of visually identified sites (mean = 22.60 m, SD = 92.14, n = 148, median = 1.00 m), but the difference is not significant assuming equal variances (P = 0.4173) or unequal variances (P = 0.0930). There is therefore no evidence of bias due to shoreline cruising; apparently, as many offshore sites were found without the aid of sonic equipment as were found with it. Knowledge of the location of these offshore sites has probably been acquired over a period of many years.

Substrate composition, proximity to inlets

All but 5 of the 208 spawning sites for which substrate composition was described were located on noncalcareous substrate. Two sites of the 5 were covered with a "calcareous marl deposit"; 2 others were on predominately noncalcareous substrate, but some of the rock consisted of "graphite bearing calcium carbonate". The fifth site was located over a natural deposit of limestone. For most sites,

assessment was based on a cursary examination of the substrate. For many sites, it was assumed that if the surrounding terrain was noncalcareous then the substrate at the site was also noncalcareous. It is possible therefore that closer examination would reveal that additional sites were located on calcareous material. Though deposits of calcareous material are rare in the interior of the Canadian Shield, they are commonly found along its margins (D. Scott, Mineral Resources Branch, OMNR, pers. comm.).

All but 1 of 221 sites described were 20 m or more from an inlet.

Susceptibility of spawning sites to acidification

Susceptibility to acidification can be assessed in 202 sites according to the criteria described in the methods section. In this assessment, sites which were described as being "close" or "next to" shore are considered to be less than 10 m from shore and sites which were described as being "offshore" are considered to be at distances greater than 10 m. Of the 202 sites, 129 or 64% met the criteria for susceptibility. That is, they had a mean depth of less than 2 m, were less than 10 m from shore, and were located on noncalcareous substrate. The one site which was less than 20 m from an inlet was classified as susceptible and is also included in the 64%.

If the depth bound is increased to include sites at 2 m and the distance bound is increased to include sites at 10 m, the number of sites which can be assessed drops to 197 (this occurs because of cases

such as one in which the site depth was not provided but the distance to shore was 10 m; if the 10 m bound is excluded the site is judged not vulnerable, if the 10 m bound is included the site susceptibility cannot be judged). Of the 197, 148 or 72% are now classified as susceptible. It is likely, based on this survey, that the majority of lake trout spawning sites in inland Ontario lakes have characteristics which make them susceptible to influxes of acidic meltwater.

In 29 of the 82 lakes in which sites were described, respondants believed that the sites described represented all of the sites in the lake. In 51 lakes, respondants believed that there were or might be additional sites, and in 2 lakes respondants were uncertain whether or not there were additional sites. For 39 of the 51 lakes in which additional sites were known or suspected, the mean number of additional sites was 5.58 (SD = 12.09). If this value is multiplied by the number of lakes in which additional sites were known or suspected, and the product is added to the number of sites described in lakes in which there were no additional sites or there were additional sites known or suspected, the total number of sites is estimated as: (5.58) 51 + 218 = 502.58. The number of sites described in questionnaires represents 43.38% of this total. This percentage underestimates the importance of the described sites however, because 1) the sites described were generally the largest and most heavily used sites on the lake, and 2) the sites described were all confirmed while the additional sites included both confirmed and suspected sites.

When respondants commented on the additional sites in a lake, the characteristics of these sites did not differ from those of sites for which a questionnaire was completed. For example, there was no tendency for the additional sites to be at greater depths.

Spawning site susceptibility, in terms of depth, distance from shore, substrate type, and distance from inlets will only be expressed in lakes which have a limited capacity to buffer inputs of acidity. Beggs et al. (1985) surveyed 1223 out of an estimated total of 2218 lake trout lakes in Ontario and predicted that in the entire province 3.7% of lake trout lakes were "acidified" (i.e. had a TIP alkalinity of < 0 mgL^{-1}) and a further 12.5% were "extremely sensitive" to acidification (i.e. had a TIP alkalinity of 0 - 1.99 mgL^{-1}). The pH of lakes in the "acidified" class will usually be less than or equal to 5.0 and the fish populations will be severely stressed (OMOE 1983). In lakes of "extreme sensitivity", the pH will probably not be toxic to most of the biota for most of the year, but the pH will almost certainly be depressed during spring snowmelt and biological damage may occur (OMOE 1983). Even in lakes of "moderate sensitivity" (TIP alkalinity: 2.00 - 9.99; 51.5% of lake trout lakes fall into this class), the pH may be depressed significantly in certain areas during snowmelt (OMOE 1983). From these observations, it is clear that a significant proportion of lake trout spawning sites in Ontario are found in lakes which are sensitive to acidification.

Site characteristics modifying susceptibility to acidification

Other site characteristics may modify the degree of impact of acidic runoff but would not likely determine whether a site is susceptible or not. For example, a site near an island or a point on the mainland might not receive as much meltwater as a site next to a broad stretch of mainland; it would receive some meltwater, however. Of the sites described in the questionnaire which were less than 10 m from shore, 42% were next to an island, 11% were next to a point on the mainland and 47% were next to a relatively broad stretch of mainland shoreline.

The depth of eggs in the substrate would also affect the extent to which they were affected by meltwater. Gunn and Keller (1984) found that interstitial water at a spawning site in Whitepine Lake maintained a higher pH ($\geq$ 5.0) than ambient water ($\geq$ 4.5) and higher inorganic Al concentrations. Because the toxic effects of inorganic Al are greatest at pH near 5.0, conditions in the interstices of the substrate would be more toxic than in the water column (Gunn and Keller 1984). It seems reasonable to further assume that a gradient of toxicity exists within the substrate. The mean range of depth distribution of lake trout egg in the substrate at surveyed sites was 3.16 cm to 19.14 cm (n = 35). The mean depth within this range averaged 8.00 cm (n = 29).

These data and other site characteristic data (shoreline slope, soil type, vegetation type) could be used together with information on lake volume and chemistry, weather patterns, and runoff volume and chemistry to predict the impact of acidic meltwater on a particular site.

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FIGURE CAPTIONS

Figure 1. Location of lakes in Ontario containing surveyed lake trout spawning sites. A = 1 observation, B = 2 observations, etc. Total number of lakes = 82.

Figure 2. Frequency distribution of mean depth of lake trout spawning sites in Ontario. In 98 of these sites, the mean depth was estimated as the midpoint between the minimum and maximum depths.

Figure 3. Relationship between lake trout spawning site mean depth and the logarithm of lake area ($r = 0.39$, $P = 0.0001$)

Figure 4. Frequency distribution of distance to shore of lake trout spawning sites in Ontario. All sites are shown.

Figure 5. Frequency distribution of distance to shore of lake trout spawning sites in Ontario. Only sites less than 10 m from shore are shown.

Figure 1

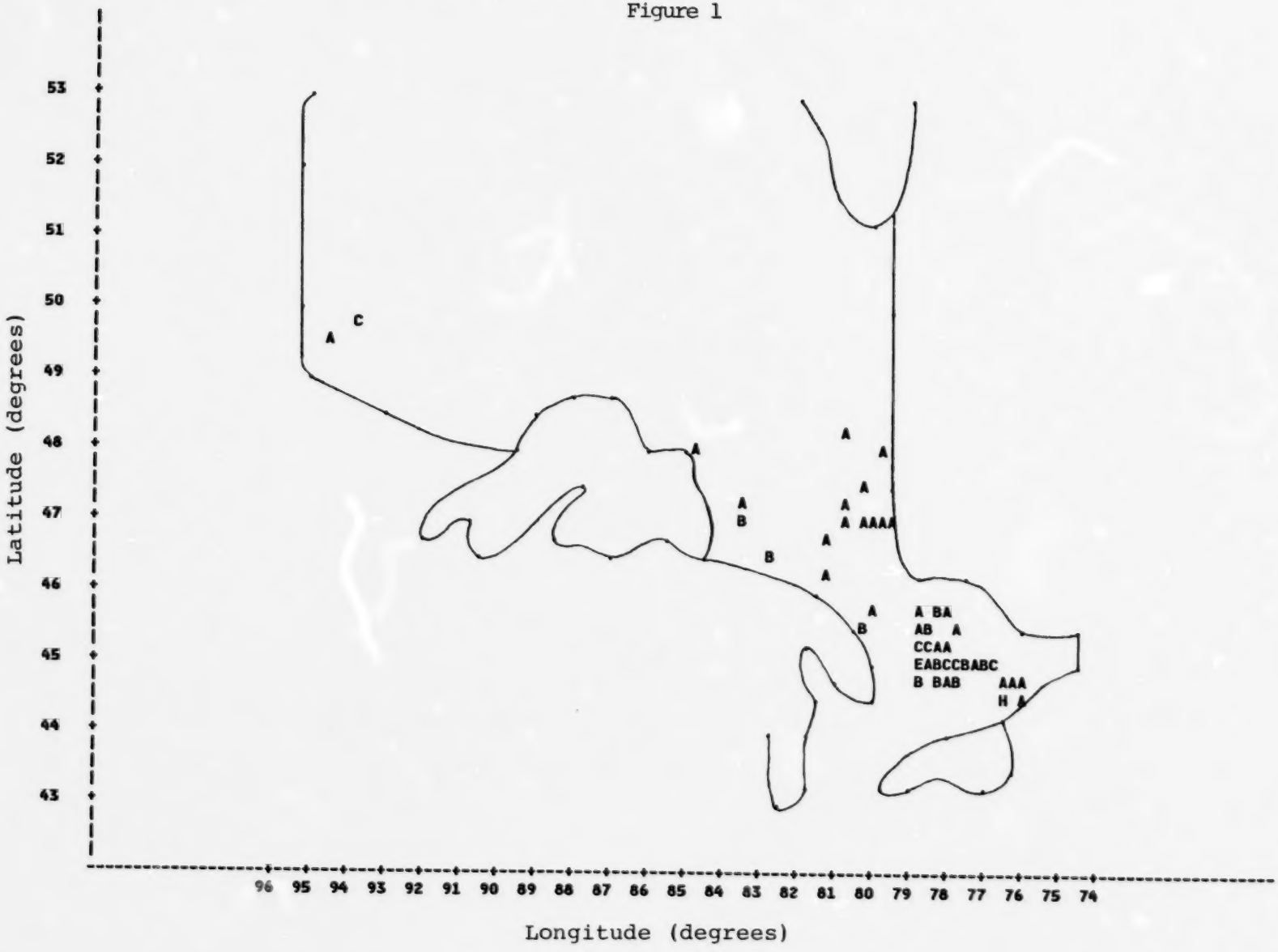
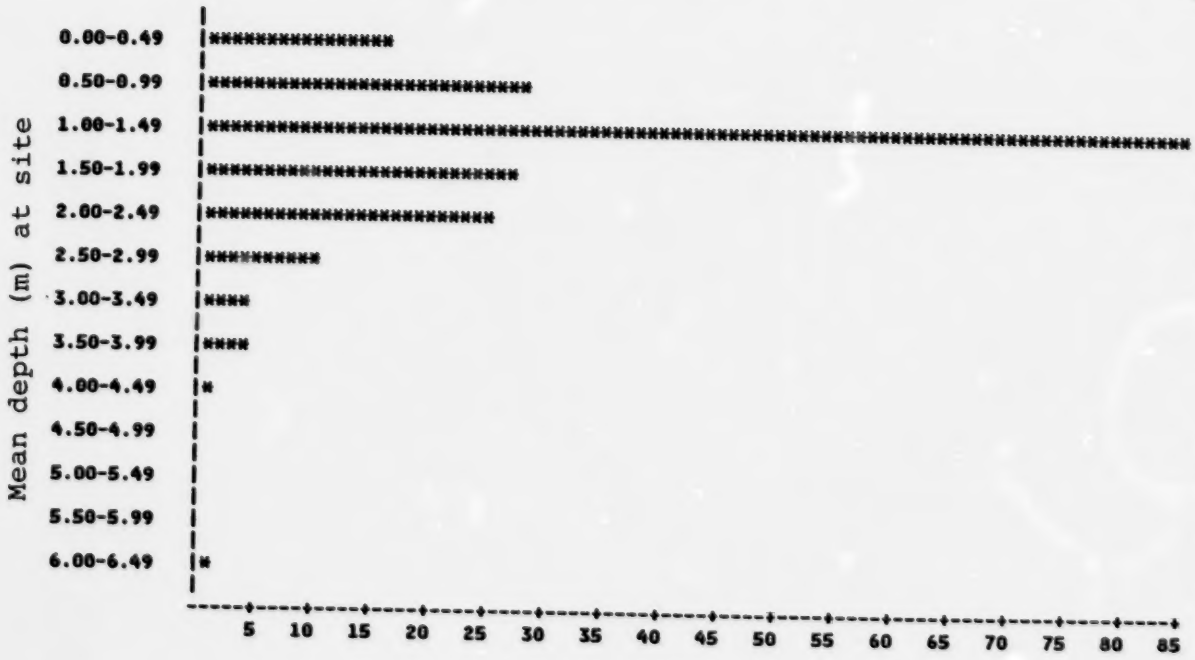

Latitude (degrees)
53
52
51
50
49
48
47
46
45
44
43
96 95 94 93 92 91 90 89 88 87 86 85 84 83 82 81 80 79 78 77 76 75 74
Longitude (degrees)

Figure 2



	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
0.00-0.49	16	16	7.96	7.96
0.50-0.99	28	44	13.93	21.89
1.00-1.49	85	129	42.29	64.18
1.50-1.99	27	156	13.43	77.61
2.00-2.49	25	181	12.44	90.05
2.50-2.99	10	191	4.98	95.02
3.00-3.49	4	195	1.99	97.01
3.50-3.99	4	199	1.99	99.00
4.00-4.49	1	200	0.50	99.50
4.50-4.99	0	200	0.00	99.50
5.00-5.49	0	200	0.00	99.50
5.50-5.99	0	200	0.00	99.50
6.00-6.49	1	201	0.50	100.00

Figure 3

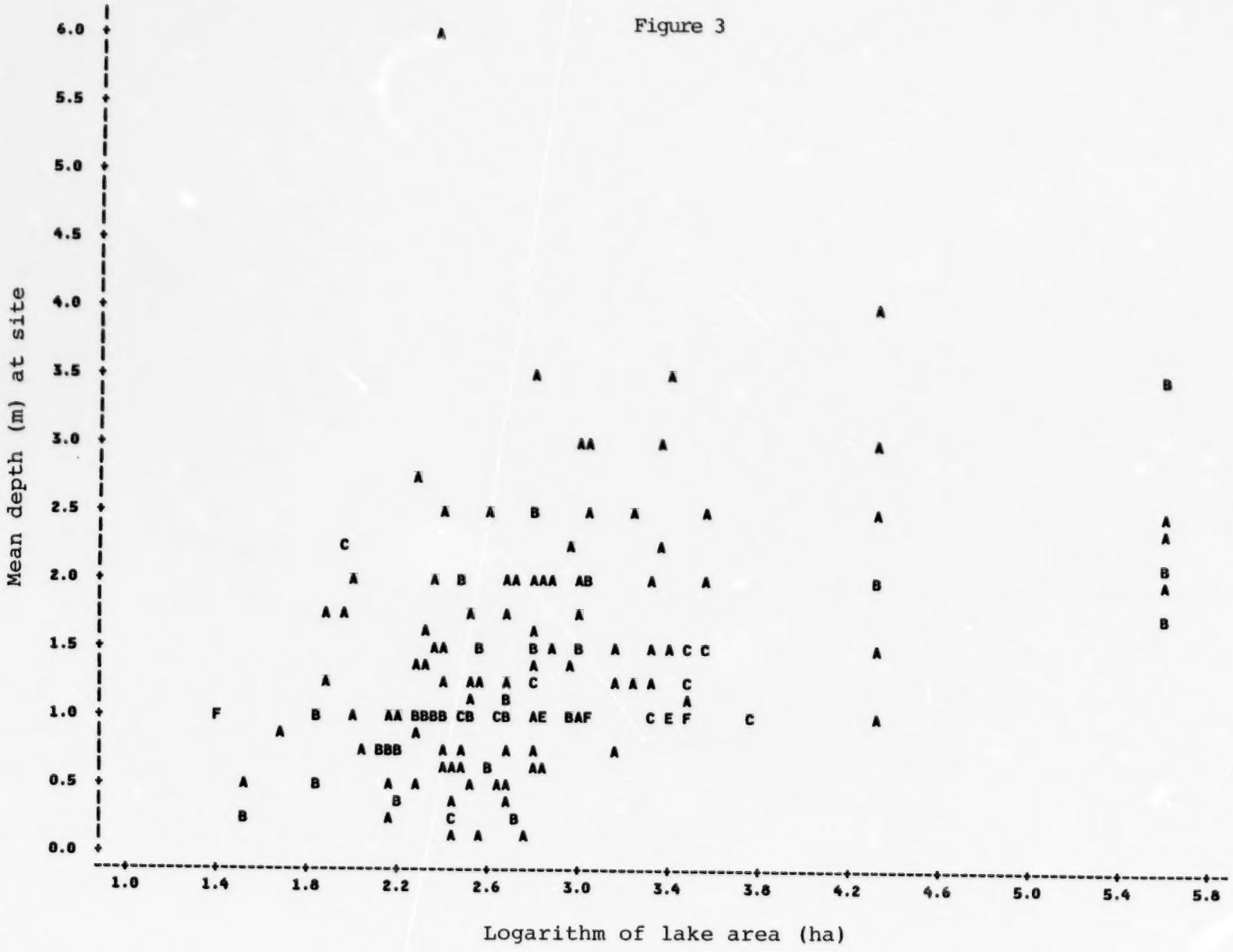
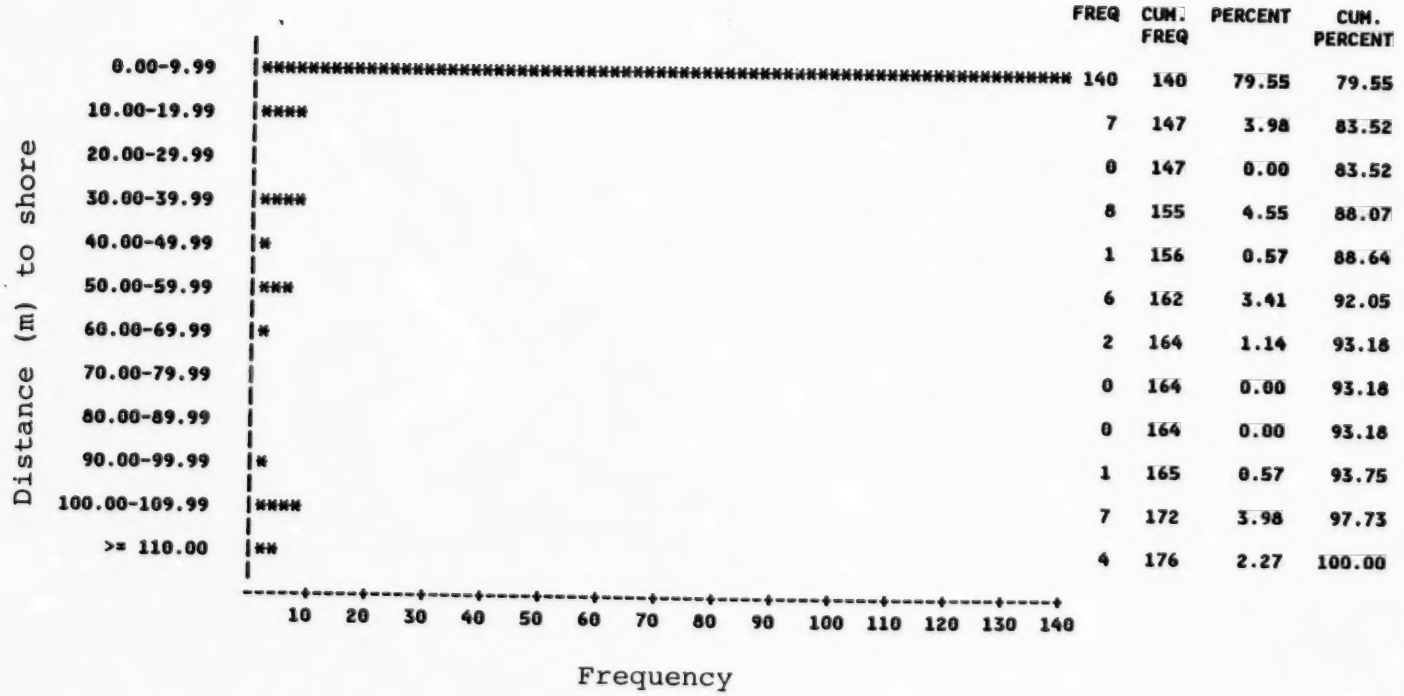
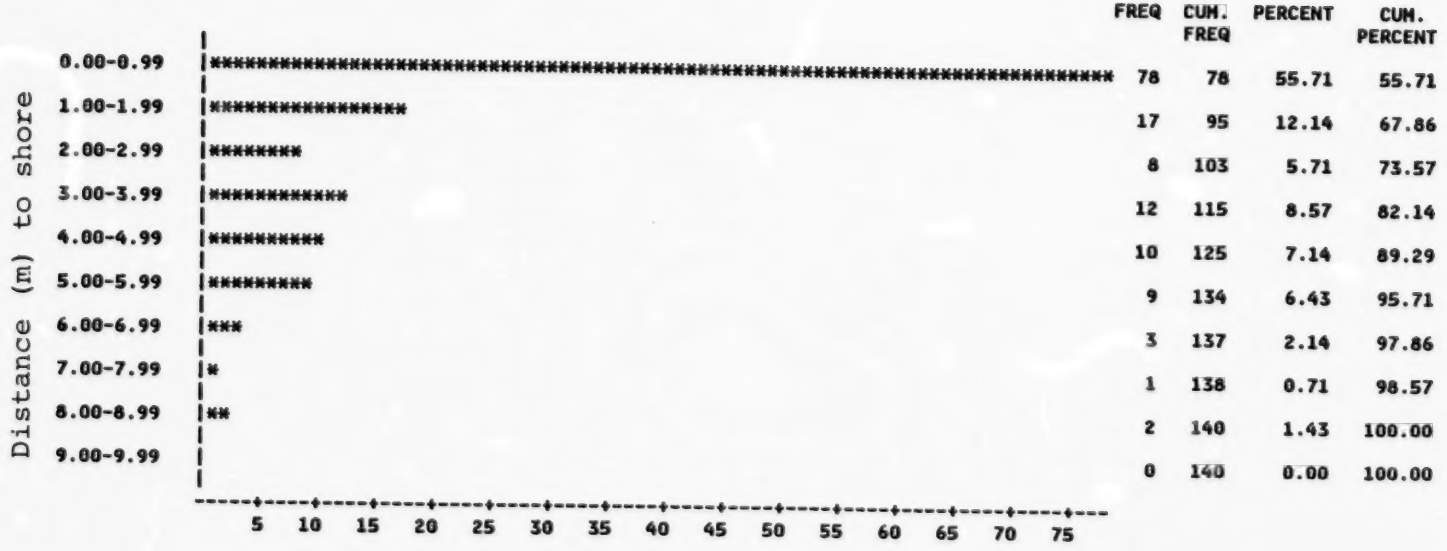

Mean depth (m) at site
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1.0
1.4
1.8
2.2
2.6
3.0
3.4
3.8
4.2
4.6
5.0
5.4
5.8
Logarithm of lake area (ha)

Figure 4



	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
0.00-9.99	140	140	79.55	79.55
10.00-19.99	7	147	3.98	83.52
20.00-29.99	0	147	0.00	83.52
30.00-39.99	8	155	4.55	88.07
40.00-49.99	1	156	0.57	88.64
50.00-59.99	6	162	3.41	92.05
60.00-69.99	2	164	1.14	93.18
70.00-79.99	0	164	0.00	93.18
80.00-89.99	0	164	0.00	93.18
90.00-99.99	1	165	0.57	93.75
100.00-109.99	7	172	3.98	97.73
>= 110.00	4	176	2.27	100.00

Figure 5



	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
0.00-0.99	78	78	55.71	55.71
1.00-1.99	17	95	12.14	67.86
2.00-2.99	8	103	5.71	73.57
3.00-3.99	12	115	8.57	82.14
4.00-4.99	10	125	7.14	89.29
5.00-5.99	9	134	6.43	95.71
6.00-6.99	3	137	2.14	97.86
7.00-7.99	1	138	0.71	98.57
8.00-8.99	2	140	1.43	100.00
9.00-9.99	0	140	0.00	100.00

APPENDIX 1

QUESTIONNAIRE ON LOCATION OF CONFIRMED LAKE TROUT SPAWNING SITES

Definitions used in this Questionnaire:

Confirmed lake trout spawning site: a site at which lake trout in spawning condition or deposited lake trout eggs have been observed by OMNR personnel.

Area of lake trout spawning site: preferably a) the area over which eggs are deposited, or, alternatively, b) the area over which lake trout in spawning condition are observed. The spawning site may therefore not necessarily cover the entire area of the shoal upon which it is located.

Name of person filling out questionnaire: _____

If the answer to any question is not known, please leave space blank.

Lake Description

1. Lake name[1] (gazetteer): _____
   (common) : _____
2. Latitude: ___° ___'
   Longitude: ___° ___'
3. Region: _____
   District: _____
4. Watershed code: _____
   Is this a headwater lake (i.e., 1st or 2nd order): _____
5. Elevation: _____ m
6. Lake area: _____ ha
7. Maximum depth: _____ m
8. Mean depth: _____ m
9. Number of confirmed lake trout spawning sites: _____

   Please mark the location of each site on a contour map of the lake and number each site so that it can be identified in the following pages.

---

[1] You may fill in only the gazetteer or common name and lat./long. if this lake has been inventoried by OMNR; we will complete questions up to and including mean depth.

Spawning Site Description

1. Spawning site number (as shown on contour map): _____
   If a map is not available, please describe in words the location of site on lake:
   _____
   _____

2. Has this site been observed on more than one year? _____ If yes, how many years? _____

   Please fill out the following questions for the year for which you have the most detailed or reliable information. If other years have major differences (in time of spawning, abundance of spawning fish, water temperature during spawning, distribution of eggs, depth of water at site, etc.), please describe these on the extra sheet provided with the questionnaire.

3. Date spawning started (day/month/year): _____
   Duration of spawning: _____

   If duration of spawning is not known, but lake trout in spawning condition or deposited late trout eggs were observed at the site, give date of observation:
   _____

4. How was this site confirmed as a lake trout spawning site? (Check as many as are applicable.)

   observation from shore _____
   observation from boat _____
   other (specify) _____
   sonic tracking _____
   emergence trapping _____
   SCUBA diving _____

5. What life stage of lake trout was observed at the site?
   adults _____
   eggs _____
   other (specify) _____

6. If adults were observed at the site, what was the total number using the site at the time of observation? (Give maximum number and minimum number if applicable.) _____

   Please circle the number on the following scale which indicates your confidence in this estimate:

1	2	3
not very confident	moderately confident	very confident

7. If eggs were observed at the site, what was their depth in the substrate?

			Confidence
maximum	____ cm.	Estimated [ ] or Measured [ ]	1 2 3
minimum	____ cm.	Estimated [ ] or Measured [ ]	1 2 3
mean	____ cm.	Estimated [ ] or Measured [ ]	1 2 3

   If estimated, please circle the number above and on the right which corresponds to your confidence in this estimate (1 = not very confident, 2 = moderately confident, 3 = very confident).

8. Water temperature at site during spawning: ____ °C to _____ °C

9. Dissolved oxygen concentration at site during spawning: _____ mgL^{-1} to _____ mgL^{-1}.

10. Depth of water at site:

			Confidence
at shallowest edge	_____ m.	Estimated [ ] or Measured [ ]	1 2 3
at deepest edge	_____ m.	Estimated [ ] or Measured [ ]	1 2 3
mean depth	_____ m.	Estimated [ ] or Measured [ ]	1 2 3

If estimated, please circle the number above and on the right which corresponds to your confidence in each estimate (1 = not very confident, 2 = moderately confident, 3 = very confident).

11. Distance from the shoreline to the nearest edge of the spawning site: _____ m. Estimated [ ] or Measured [ ]. If estimated, circle the number on the following scale which indicates your confidence in this estimate:

1	2	3
not very confident	moderately confident	very confident

12. The nearest shoreline is:

an island	_____
mainland	_____
a point on the mainland	_____

13. Area of site: _____ m^2. (See definition on page 1.) Is this:
a) area over which eggs are deposited? [ ]
b) area over which spawning activity has been observed? [ ]
Estimated [ ] or Measured [ ].

14. Percentage of site covered by various types of substrate:

flat rock	_____ %
boulders (30cm-1m in diameter)	_____ %
rubble (5-30cm in diameter)	_____ %
gravel (0.1-5cm in diameter)	_____ %
sand	_____ %
clay	_____ %
other (specify) _____	_____ %

15. Composition of substrate:

granite	_____
limestone	_____
other (specify) _____	

16. Percentage of substrate covered with the following:

silt	_____ %
detritus	_____ %
algae	_____ %
macrophytes	_____ %

17. General slope of lake bottom at site:
level _____
slight slope (0-20°) _____
moderate slope (20-45°) _____
slope >45° _____

18. Is the spawning site near an inlet? _____ If yes, give distance and describe type of inlet (river, stream, spring, etc.): _____ m type _____

19. Prevailing wind direction at site: _____

20. Fetch at site: _____ km

21. Slope of shore nearest site:
level _____
slight slope (0-20°) _____
moderate slope (20-45°) _____
slope >45° _____

22. What does this shore consist of?
exposed rock _____
thin soil layer over rock _____
thick soil layer over rock _____
other (specify) _____

23. Distance from water's edge to shore vegetation: _____ m.

24. Type of vegetation on shore:
grasses, sedges _____
shrubs _____
coniferous trees _____
deciduous trees _____
mixed forest _____
other (specify) _____

25. Do you think the confirmed spawning site(s) described in this questionnaire represent(s) all of the lake trout spawning sites in this lake? _____ If not, how many additional sites may there be? _____

26. Do you have additional chemical data on this spawning site or on the lake in which this site is located? If so, please list parameters measured.
spawning site: _____
lake : _____

27. Do you have any further comments on the location of lake trout spawning sites or on this questionnaire? _____

APPENDIX 2. Lake trout spawning site questionnaire respondants.

Respondant	Affiliation
C. Brady	Haliburton-Hastings Fisheries Assessment Unit, OMNR
J. Brisbane	Bancroft District, OMNR
J. Casselman	Fisheries Research Section, Maple, OMNR
G. Deyne	Timmins District, OMNR
G. Gillespie	Leslie M. Frost Natural Resources Centre, OMNR
J. Hamilton	Booth Aquatic Research Group, Inc., Toronto
D. Jeffrey	Algonquin Fisheries Assessment Unit, OMNR
V. Liimatainen	Sudbury District, OMNR
V. Macins	Lake of the Woods Fisheries Assessment Unit, OMNR
N. MacLean	Rideau Lakes Fisheries Assessment Unit, OMNR
N.V. Martin	Fisheries Research Section, Maple, OMNR (retired)
K. Mills	Department of Fisheries and Oceans, Winnipeg
A. Palilionis	Napanee District, OMNR
M. Pellegrini	Wawa District, OMNR
D. Read	Temagami District, OMNR
B. Renaud	Kirkland Lake District, OMNR
T. Stewart	Acidification Study Group, Dorset, OMNR
E. Thomas	Sault Ste. Marie District, OMNR
L. Thurston	Parry Sound District, OMNR
D. Wilson	Minden District, OMNR

APPENDIX 3. Lakes in which lake trout spawning sites were described.

Lake	District	Lat.(°N)	Long.(°W)	Number of sites described
223	Kenora	49°40'	93°40'	5
224	Kenora	49°40'	93°40'	1
Roddy	Kenora	49°41'	93°44'	3
Dickey	Bancroft	44°47'	77°44'	2
Twelve Mile	Minden	45°01'	78°43'	3
Drag	Minden	45°04'	78°23'	3
Clear	Napanee	44°33'	76°28'	3
Salmon	Napanee	44°32'	76°30'	4
Devil	Napanee	44°35'	76°27'	10
Rideau	Brockville	44°45'	76°13'	3
Charleston	Brockville	44°32'	76°00'	5
Wawa	Wawa	48°01'	84°43'	3
Smoke	Algonquin Park	45°31'	78°41'	6
White Partridge	Algonquin Park	45°50'	78°06'	1
Timberwolf	Algonquin Park	45°41'	78°48'	1
Delano	Algonquin Park	45°32'	78°34'	2
Lavieille	Algonquin Park	45°51'	78°14'	5
Louisa	Algonquin Park	45°28'	78°29'	6
Aylen	Algonquin Park	45°37'	77°51'	4
Wahwashkesh	Parry Sound	45°43'	80°02'	2
Lake of the Woods	Kenora	49°30'	94°30'	9
Temagami	Temagami	47°00'	80°05'	7
Obabika	Temagami	47°05'	80°17'	13
Rabbit	Temagami	47°00'	79°38'	1
Cooper	Temagami	47°03'	79°30'	1
Mendelssohn	Temagami	47°32'	80°12'	1
Radisson	Timmins	48°13'	80°45'	1
Larder	Kirkland Lake	48°05'	79°38'	5
Kushog	Leslie M. Frost Nat.Res.Centre	45°04'	78°47'	2

Appendix 3...continued

Lake	District	Lat.(°N)	Long.(°W)	Number of sites described
Allen	Bancroft	45°07'	78°15'	2
Anstruther	Bancroft	44°45'	78°12'	3
Baptiste	Bancroft	45°07'	78°03'	4
Bay	Bancroft	45°01'	77°52'	1
Big Mink	Bancroft	45°15'	78°05'	1
Chandos	Bancroft	44°49'	78°00'	3
Deer	Bancroft	45°02'	78°06'	2
Eels	Bancroft	44°54'	78°08'	3
Fishtail	Bancroft	45°09'	78°12'	3
Jamieson	Bancroft	45°04'	77°41'	1
L'Amable	Bancroft	45°01'	77°49'	2
Limerick	Bancroft	44°53'	77°37'	1
Long	Bancroft	44°41'	78°10'	3
Mayo	Bancroft	45°02'	77°35'	1
Mephisto	Bancroft	44°56'	97°35'	1
Silent	Bancroft	44°55'	78°04'	1
Wollaston	Bancroft	44°51'	77°50'	3
Ranger	Sault Ste.Marie	46°54'	83°34'	2
Megisan	Sault Ste.Marie	47°15'	83°32'	1
Gong	Sault Ste.Marie	47°01'	83°33'	1
Elliot	Blind River	46°23'	82°42'	1
Flack	Blind River	46°35'	82°47'	1
Big Ohlman	Tweed	45°03'	77°00'	3
Crow	Tweed	44°36'	76°25'	2
Mackie	Tweed	45°05'	76°49'	3
Palmerston	Tweed	45°01'	76°51'	2
Shabomeka	Tweed	44°54'	77°08'	6
Sharbot	Tweed	44°56'	76°41'	4
Wensley	Tweed	45°03'	77°03'	1

Appendix 3...continued

Lake	District	Lat.(°N)	Long.(°W)	Number of sites described
Otter	Brockville	44°47'	76°07'	2
Silver	Carlton Place	44°50'	76°36'	1
Kimball	Bracebridge	45°21'	78°41'	2
Clear	Leslie M.Frost Nat. Res. Centre	45°11'	78°43'	3
Sherborne	Leslie M. Frost Nat. Res. Centre	45°11'	78°47'	3
Trout	Parry Sound	45°35'	80°10'	2
Miskokway	Parry Sound	45°35'	80°10'	1
Desert	Napanee	44°32'	76°35'	2
Buck	Napanee	44°32'	76°26'	2
Loughborough	Napanee	44°25'	76°29'	1
Birch	Napanee	44°33'	76°32'	1
Clean	Minden	45°15'	78°32'	2
MacDonald	Minden	45°15'	78°34'	2
Whitepine	Sudbury	47°17'	80°50'	4
Panache	Sudbury	46°15'	81°20'	2
Laundrie	Sudbury	47°05'	80°52'	1
Michaud	Sudbury	46°49'	81°14'	1
Shirley	Algonquin Park	45°41'	78°08'	2
Boshkung	Minden	45°04'	78°44'	3
Bob	Minden	44°55'	78°47'	1
Davis	Minden	44°47'	78°43'	1
Moose	Minden	45°09'	78°28'	2
Mountain	Minden	44°59'	78°43'	3
Gull	Minden	44°51'	78°47'	3

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